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Relative Strength of Wet & Dry Concrete

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RELATIVE STRENGTH

OF

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BY

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OF Bachelor of Science in Civil Engineering

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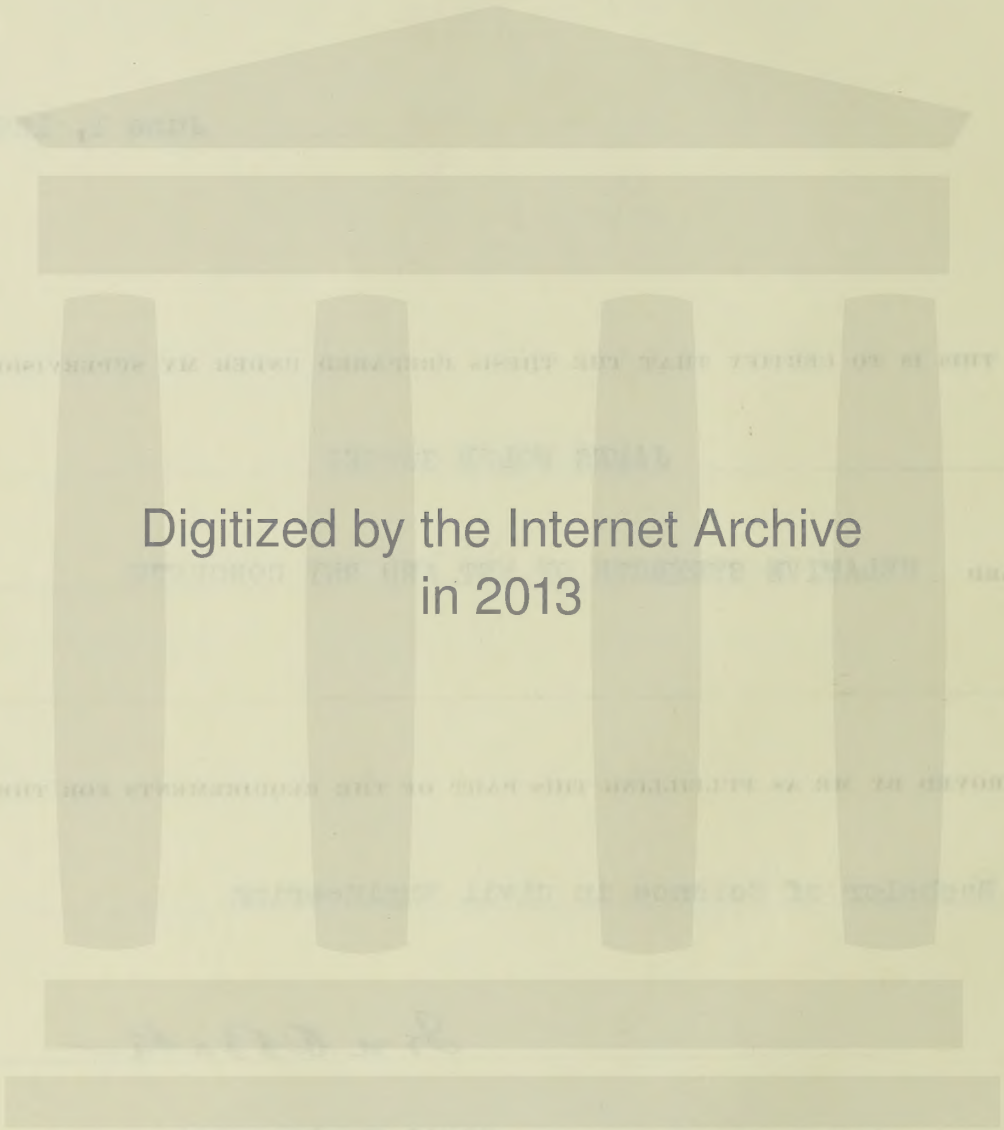
HEAD OF DEPARTMENT OF Civil Engineering.



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Relative Strength of Wet and Dry Concrete.

The use of concrete as a building material has become so general that numerous tests have been made to determine the correct proportions of ingredients and the proper kinds of materials to be used, but very few experiments have been made to determine the relative strength of concrete having different degrees of plasticity. The importance of water as a constituent in concrete is evidenced from the dis-

discussion of the subject in the various engineering societies and in technical literature.

The only reports of experiments not readily accessible that the writer has been able to find are given in the Journal of the Western Society of Engineers for October, 1900, and June, 1902. The former is a description of an experiment by Mr. Irving Hill of the Chicago, Milwaukee and St. Paul Railroad, and the latter is a report of an experiment made under the direction of Mr. F. H. Parkhurst of the Illinois Central Railroad. Mr. Hill's experiment consisted

in making two cubes with different plasticities, each containing about a yard of masonry, and were split open with wedges at the age of one month. Mr. Fritz's conclusions were: "1. A moderate excess of water is not injurious. 2. More labor is necessary in mixing and placing a dry, or moderately dry, mixture than a wet one. 3. It is impossible to get a compact concrete without using what is theoretically an excess of water." The experiment conducted by Mr. Parkhurst consisted in making three cubes with different plasticities, each

containing about a yard of concrete and broken open with wedges when one month old. Mr. Parkhurst's conclusion was that a medium concrete is the strongest.

Owing to the lack of definite data on the subject and the importance of knowing the effect of a deficiency or an excess of water, the following experiments were made. Forty-five six-inch cubes were made with three percentages of water and were broken on a testing machine at three ages. The amount of water used was: for dry concrete 6.0 per-

each, for medium 7.4 and for coat 7.4. The concrete was made of the following ingredients: Chicago A1 portland cement, sand containing a small percent of fine gravel, and crushed limestone which would pass through a mesh of one inch mesh. The ingredients were mixed in the proportion of one volume of loose cement, three volumes of sand, and six of broken stone.

The plasticity of the concrete with the given percents of water was such that

earth and when squeezed in the hands the mortar would retain its shape and when thoroughly tamped no free water would flush to the surface. The medium concrete would neither quake in handling nor when slightly tamped, but when well tamped water would flush to the surface and the concrete would quake. The wet concrete quaked in handling and would be tamped only slightly.

The wet and dry mixtures fairly represent the range in practice. The medium concrete fulfils the common specification that

"the concrete shall be of such consistency that water will flush to the surface when well tamped but will not quake in handling."

The cubes were moulded in gang moulds containing three compartments and the cubes from each gang constituted one set.

The tamping was done with a cast iron rammer having a face of 2½" x 2½" weighing 11½ pounds dropped six inches.

Two degrees of tamping were used, one consisting of twenty blows per one-inch layer and the

others of three thousand pounds. The work done in tamping may be stated as $11\frac{1}{3} \times \frac{1}{2} \times 20 \times 6 =$ 680 foot-pounds per cube for the hard tamping, and $11\frac{1}{3} \times$ [illegible] $=$ 540 for the light tamping.

In making the cubes great care was exercised to get uniform results. Each set was made of the same mixture and the three cubes in each set were made at the same time.

When completed each cube with the mould was placed [illegible] cubes, and the concrete was allowed to remain in the moulds for twenty-four hours, after which the moulds were [illegible]

knocked down and the cubes placed in water until time for them to be broken.

The cubes were broken at three ages, viz. seven days, one month, and three months. The object of the seven day test was to determine the reliability of an absorption test rather than to draw any definite conclusions on the relative strength of sand and dry concrete.

The cubes were broken in an Olsen testing machine of 200,000 lbs. capacity. The machine is provided with a ball and socket joint which is placed over the center and

under the crushing face of the machine. This device eliminates the necessity of making the top and bottom faces of cubes exactly parallel and gives an even bearing.

The results of the experiments are given in the following tables. The wet concrete became sloppy after slight tamping and further attempt at tamping was ineffective; and therefore no results of wet concrete with hard tamping could be obtained. For comparison, however, the results of lightly tamped wet concrete may be inserted in the table showing results of concrete with hard tamping.

TABLE I

Results of Tests of Cement Mortar.

Age: 1 Week.

Reference Number	Plasticity	Tamping	CRUSHING STRENGTH		
			Total lbs.	Lbs. per sq. in.	Tons per sq. ft.
1	Dry	Light	46800	1300	93.6
2	"	"	41700	1160	83.4
3	"	"	41800	1160	83.6
	Mean =		43400	1210	86.9
4	Dry	Hard	46300	1290	92.6
5	"	"	46500	1290	93.0
6	"	"	52000	1440	104.0
	Mean =		48300	1340	96.5
7	Medium	Light	86600	2400	173.2
8	Medium	Light	80600	2230	161.2
9	"	"	80000	2220	160.0
	Mean =		82400	2250	164.8
10	Medium	Hard	46800	1300	93.6
11	"	"	51100	1420	102.2
12	"	"	45500	1260	91.0
	Mean =		47800	1330	95.6
13	Wet	Light	38300	1060	76.6
14	"	"	36600	1020	73.2
15	"	"	37400	1050	75.8
	Mean =		37600	1040	75.2

TABLE II

Results of Tests of Concrete Cubes.

Age: 1 Month.

Reference Number	Plasticity	Tamping	CRUSHING STRENGTH		
			Total lbs.	Lbs. per sq. in.	Tons per sq. ft.
16	Dry	Light	55000	1530	110.0
17	"	"	63000	1750	126.0
18	"	"	71100	1970	142.2
		Mean =	63000	1750	126.1
19	Dry.	Hard	67400	1870	134.8
20	"	"	70800	1970	141.6
21	"	"	73800	2050	147.6
		Mean	70600	1960	141.3
22	Medium	Light	86600	2400	173.2
23	"	"	80600	2240	161.2
24	"	"	80000	2220	160.0
		Mean =	82400	2290	164.8
25	Medium	Hard	95200	2640	190.4
26	"	"	91800	2550	183.6
27	"	"	90000	2500	180.0
		Mean =	92300	2560	184.6
28	Wet	Light	85200	2370	170.4
29	"	"	79500	2210	159.0
30	"	"	76300	2120	152.6
		Mean =	80300	2230	160.6

TABLE III

(Results of Tests of Concrete Cubes

Age: 3 Months.

Reference Number	Plasticity	Tampility	CRUSHING STRENGTH		
			Total Lbs.	Lbs. per sq. in.	Tons per sq. ft.
31	Dry	Light	87100	2420	174.2
32	"	"	88400	2460	176.8
33	"	"	94000	2610	188.0
		Mean=	89800	2490	179.7
34	Dry	Hard	90000	2500	180.0
35	"	"	92400	2570	184.8
36	"	"	98400	2730	196.8
		Mean=	93600	2600	187.2
37	Medium	Light	76000	2110	152.0
38	"	"	76300	2120	152.6
39	"	"	80700	2250	161.8
		Mean=	77400	2160	155.5
40	Medium	Hard	99300	2760	198.6
41	"	"	90500	2510	181.0
42	"	"	89500	2490	179.0
		Mean=	93100	2590	186.2
43	Wet	Light	110900	3070	221.4
44	"	"	110400	3060	220.8
45	"	"	106700	2970	213.4
		Mean=	109300	3030	218.5

TABLE IV.

Summary of Tests.

Reference Number	Plasticity	Mean Crushing Strength	Ratio of Strength
	Light Tamping		
	Age:	1 week	
1-3	Dry	43400	0.533
7-9	Medium	82400	1.000
13-15	Wet	37600	0.462
	Age:	1 month	
16-18	Dry	63000	0.764
22-24	Medium	82400	1.000
28-30	Wet	80300	0.973
	Age:	3 mos.	
31-33	Dry	89800	1.160
37-39	Medium	77400	1.000
43-45	Wet	109300	1.412
	Hard	Tamping	
	Age:	1 week	
4-6	Dry	48300	1.007
10-12	Medium	47800	1.000
	Age:	1 month	
19-21	Dry	70600	0.765
25-27	Medium	92300	1.000
	Age:	3 mos.	
34-36	Dry	93600	1.005
40-42	Medium	93100	1.000

since this is the maximum strength obtainable with wet concrete.

Conclusions.

These experiments show that one or three month test, wet concrete has greater strength than either dry or medium concrete. For a shorter test a medium concrete gives the greatest strength. There is no condition of age or tamping which shows dry concrete to be the strongest.

By using a rather wet mixture a compact mass can be obtained with comparatively little tamping, while a dry mixture on the

other than it, does not make a compact mass with any amount of tamping. In Table III, it is seen by comparing Nos. 40, 41 and 42 with Nos. 43, 44 and 45, that wet concrete with light tamping is stronger than either dry or medium concrete with hard tamping. Therefore wet concrete is cheaper than dry and is also better.

In breaking the cubes it was noticed that the wet concrete was distorted more than the dry before failure occurred, which fact shows that wet concrete is more elastic than dry.

The conclusions of these experiments may be

stated briefly as follows:

1. Dry concrete should never be used under any circumstances.

2. Medium concrete may be used where immediate strength is desired.

3. Wet concrete is stronger than dry or medium, at an age at least over three months.

Suggestions for continuation of work on this subject.

As a result of experience in the tests of wet and dry concrete the writer would suggest that five ages be used instead of three, viz: one week, one, two, three and four months. This would give data on the rate

of increase in strength with different plasticities. If curves showing strength at different ages are plotted this will give five points on the curve, which is about the minimum for definite conclusions on rate of increase in strength.

An improvement would be made in tamping if the hard tamping consisted of ten blows from one inch drop instead of twenty, and the light tamping five instead of ten. By this arrangement data could be obtained on hard and light tamping of wet concrete, ten blows being about the maximum tamping

attainable with wet concrete.

The relative elasticity of wet and dry concrete could be determined quite accurately by measuring the deformation of the cubes from the time pressure is applied until the maximum strength is reached. This could be done by using the same speed on all cubes and comparing the time required to crush them, or it may be done by measuring the actual distance the crushing face moves through after pressure was applied.

No less than three cubes should be used for one set, and on the other hand, three cubes give very satisfactory results.

The plasticity used in these experiments was very satisfactory.

In conclusion the writer would suggest the following changes from the method used in these experiments, viz:

1. Use five ages instead of three, if this makes too many cubes omit the one week test.

2. Use lighter tamping.

3. Determine the relative elasticities.